INSTITUTE OF PETROLEUM REVIEW

VOL. 3. No. 31. JULY 1949. Price 2/–. Annual Subscription: One Guinea

TRADE ONLY

THE HALL MARK OF QUALITY

LUBRICANTS

ECLIPSOL OIL CO. LTD.

WEST BROMWICH

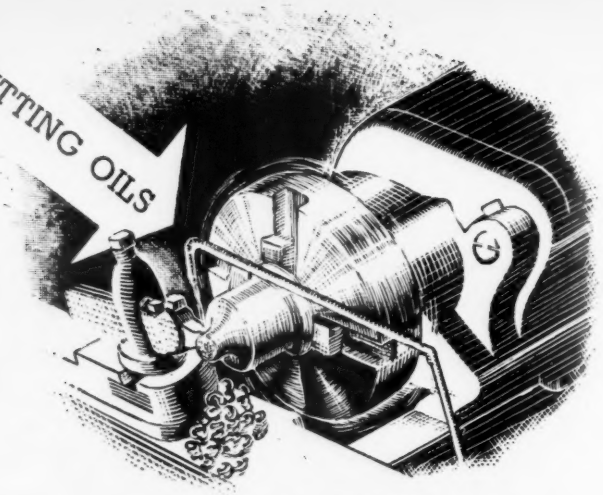
PHONE:
WEST BROMWICH 0431-2-3-4

GRAMS:
SOLUBLE, WEST BROMWICH

PUBLIC LIBRARY
AUG 23 1949
DETROIT

PUBLISHED BY THE INSTITUTE OF PETROLEUM
26, Portland Place, London, W.1 . Telephone No. LANgham 2250

FOR CUTTING OILS



& CUTTING COSTS

SULPHURISED OILS

ARE INVALUABLE E.P. COMPONENTS

★HIGH TOTAL SULPHUR WITH
LOW FREE-SULPHUR CONTENT

★NON-CORROSIVE, NON-STAINING
WITH YELLOW METALS

More than an Additive
More than a Base . . .

ANCHOR CHEMICAL COMPANY LTD.
MANCHESTER 11

London Office: Grand Buildings, Trafalgar Square, W.C.2

Scottish Agents: J. & G. Hardie & Co. Ltd., 178 Fulton St., Glasgow, W.3

INSTITUTE OF PETROLEUM REVIEW

Hon. Editor: F. H. Garner, O.B.E., Ph.D., F.R.I.C.
Hon. Associate Editor: E. B. Evans, Ph.D., M.Sc., F.R.I.C.
Editor: George Sell

No. 31 **JULY 1949** Vol. 3

CONTENTS

Significance of Properties of Petroleum Products (Introduction)	193	Special General Meeting	210
I. Specific Gravity by F. H. Garner	194	A Message from the President	210
Automobile Design: Basic Problems and Current Practice by M. S. Crosthwaite	197	Fawley Refinery	211
Petroleum in Parliament	206	Personal Notes	211
I.P. Golf Meeting	206	The Purpose and Evolution of Oil Fuel Specifications by C. W. G. Martin and D. R. Bailey	213
Council Commentary	208	New Marine Bunker Facilities at Algiers	220
		M.I.R.A. Proving Ground	221

SIGNIFICANCE OF PROPERTIES OF PETROLEUM PRODUCTS

INTRODUCTION

In order to select the most suitable petroleum product for an industrial use, a knowledge of test methods and their significance is essential since the properties of the petroleum product will be expressed in a specification comprising a number of figures quoted in terms of standard methods of test. A detailed knowledge is necessary of the meaning of the figures quoted with reference both to the product itself and to the industrial purpose for which it is to be used, and in addition some of the specification figures will have to be considered together.

The Publications Committee therefore thought it would be helpful to prepare a series of articles which were expressed in simple language, dealing with the more important tests described in our own and other standard methods of test.

Petroleum products were developed for use primarily as fuels and lubricants, and a series of methods of test were designed and standardized to simulate the behaviour of the product under conditions in which the product was to be used. Many of the methods were peculiar to the petroleum industry, and both the apparatus and the details of the test had to be carefully standardized as, for example, the flash-point test, originally designed to eliminate the possibility of explosion when kerosine is burnt in lamps. The flash-point method was the first of a series of methods of test which do not determine a fundamental property, such as specific gravity or sulphur content. Tests of similar character are pour-point, demulsification, drop-point, penetration, and knock rating, which all give a measure of some important property required in practice and based more or less on the conditions of use. The success of such methods depends on how completely the laboratory apparatus and test method can duplicate practice and also give concordant results

when the apparatus and method are used in a number of different laboratories.

Amongst the tests which do determine fundamental properties are chemical tests such as sulphur determination, water content, aromatic content, and salt content; associated with these are methods for the determination of groups of chemical compounds, such as asphaltene determination.

The purely physical tests include specific gravity, surface tension, refractivity, and viscosity, although the latter is also determined, less accurately, in empirical apparatus such as the various types of commercial viscometers, including the Redwood. Another very important physical test is the distillation method, which again is carried out in a simple apparatus which does not effect complete separation of the hydrocarbons present in profusion in petroleum products.

In this series of articles an attempt has been made to discuss the significance of a selected number of the more important test methods and their relevance to the particular purposes for which the product is used. These purposes, in most instances, will refer to the utilization of the product, but there are certain tests which have their importance either in the process of measuring oil quantities or in checking up the efficiency of chemical and physical refining processes in the refinery. Since the same essential property is determined by different methods of test according to the purpose for which it is applied, as, for example, volatility by flash-point, distillation or vapour pressure, reference is made in the articles to the relevant methods of test in the Institute of Petroleum standard test method book, together with, where necessary, references to the corresponding A.S.T.M. methods and other especially important publications.

I. SPECIFIC GRAVITY

By F. H. GARNER, O.B.E. (Fellow)

SPECIFIC gravity is one of the few purely physical properties determined on petroleum products, since most of the methods of test are designed to imitate conditions of use, as, for example, flash-point. By itself, specific gravity is of little value as an indication of the quality of a petroleum product, but taken in conjunction with other methods of test, it can be used to evaluate product quality.

Specific gravity is normally determined on all liquid petroleum products, since these are usually measured by volume, whereas for the estimation of a true material balance, as, for example, the yields of various petroleum products from crude petroleum in a refinery, weight is required. Weights are strictly additive, whereas volumes are not, since the volumes obtained by blending various petroleum products are not necessarily the same as those obtained by adding the volumes of the components.

In the United Kingdom, specific gravities are measured at 60° F in comparison with water at the same temperature; thus specific gravity is the ratio of the mass of a given volume of oil to the mass of the same volume of distilled water, the temperature of both being taken at 60° F. In the United States of America the A.P.I. (American Petroleum Institute) scale is used instead of specific gravity, but is based on specific gravity at 60° F, using the following formula:

$$\text{Degrees A.P.I.} = \frac{141{\cdot}5}{\text{Sp. gr. } 60^\circ\text{F}/60^\circ\text{F}} - 131{\cdot}5.$$

This scale is a modification of the Beaume scale which, however, has the

modulus of 140 instead of 141·5 and the corresponding figure of 130 (140—10) instead of 131·5 shown in the A.P.I. scale; the modified scale was adopted because a considerable number of hydrometers in use were in error by the consistent amount indicated between the two scales. On the continent of Europe and in Latin-American countries, which use the Centigrade scale, density at 15° C is used rather than specific gravity at 60° F. Density at 15° C is the ratio of the weight of a given volume of oil at 15° C to that of the same volume of distilled water at 4° C, and since this latter is by definition equal to the volume in millilitres, density is the mass of the oil occupying unit volume at 15° C; it is thus not a ratio as is specific gravity.

For solid products such as asphaltic bitumen and paraffin waxes, weights are directly determined, but specific gravities are often required for the liquefied product at raised temperatures. For asphaltic bitumens, the specific gravity is reported at 77° F (25° C) instead of the normal 60° F.

Volumes of petroleum products in storage are measured at the prevailing temperature, which for the more volatile products may be below 60° F in the winter season and for those more viscous products which are artificially heated, will be above 60° F. Average samples of the petroleum product are taken, and specific gravities are determined and corrected to the specific gravity at 60° F by use of the appropriate correction tables given in "Tables for Measurement of Oil" published by the Institute of Petroleum. Gasoline and kerosine are sold wholesale and retail by the gallon, measured at the temperature of sale, and consequently the weight varies according to the season of the year, being larger in the winter-time. Thus there may be a loss or gain according to the season in distribution from the main storage tanks of which the content is based always on 60° F.

In order to obtain the volume of oil at 60° F (which is necessary for conversion to a weight basis) volume correction factors are used which are based on specific gravity since the coefficient of expansion is higher the higher the specific gravity. In "Tables for Measurement of Oil", correction factors are given for specific gravity ranges from 0·600 to 0·609 to 1·090 to 1·099, together with the appropriate correction factor for the petroleum product over a wide range of temperatures. It is important to note that the volume correction is quite different from the specific gravity correction factor, since the latter is based on the ratio of masses of equal volumes of oil and water.

The normal method for the determination of the specific gravity of less volatile petroleum products is by means of hydrometers which are calibrated to indicate specific gravities corrected for the buoyancy effect of air (I.P. 59/45). With more viscous products the temperature may be raised to reduce the viscosity so that the hydrometer rapidly finds its own level, but it is also customary for accurate determination of the specific gravity to use the normal pyknometer method (I.P. 59/45). Hydrostatic balances such as the Westphal are also employed for determination of the specific gravity of the less viscous products. For asphalts, a number of methods are in use, based on the measurement of volume by the displacement of water; and for gases methods based on direct weighing and on the rate of effusion have been standardized.

Specific gravity has also its special importance in the control of refinery operations as an indication of the uniformity of the product. Calorific value and other thermal properties of petroleum products are closely related to the specific gravity of the product, and fairly accurate estimates of these properties can be obtained from a knowledge of the specific gravity, using tables such as those given by Cragoe in

U.S.B.M. Publication No. 97. As an indication of quality it has its value in conjunction with the results of other methods of test, particularly the distillation test. For a given volatility, high specific gravities are normally associated with the presence of aromatic hydrocarbons or compounds of high carbon-hydrogen ratio and correspondingly low specific gravities with the presence of paraffin hydrocarbons or hydrocarbons of low carbon-hydrogen ratio.

The carbon-hydrogen ratio has a most important bearing on the quality of petroleum products, and thus high carbon-hydrogen ratio in straight-run gasolines is usually associated with good anti-knock value; in kerosines, with poor smoke points; in straight-run gas oils with poor ignition quality; and in lubricating oils, with poor viscosity temperature ratio. However, even where the carbon-hydrogen content ratio is constant, as for example the various octanes, specific gravity varies and also the anti-knock quality, but not necessarily in step with one another.

When, however, specific gravity is used in conjunction with another test indicating the aromaticity or paraffinicity, as for example the aniline point determination, useful information can be obtained. Thus the diesel index (*A.P.I. gravity* × *aniline point in °F*/100) has been widely used as a measure of ignition quality of diesel fuels.

Thus specific gravity has its own special importance in the petroleum industry, being the most widely used test method, although it is not usually an essential specification requirement.

SUGGESTIONS FOR FURTHER READING:

"Tables for measurement of oil." Institute of Petroleum, 1945.

"Measurement of oil in bulk. Standard weights and measures." Institution of Petroleum Technologists, 1932.

"Thermal properties of petroleum products." Bureau of Standards Misc. Publn. No. 97. Washington, 1933.

I.P. Method 59 45. Definition of density and specific gravity, and methods for gases, liquids and solids.

ASTM Method D287–39. Gravity of petroleum and petroleum products by means of the hydrometer.

ASTM D70–27. Specific gravity of road oils, road tars, asphalt cements, and soft tar pitches.

ASTM D71–27. Specific gravity of asphalts and tar pitches sufficiently solid to be handled in fragments.

ASTM D268–46. Specific gravity of lacquer solvents and diluents.

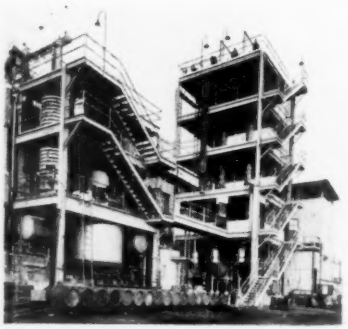
ASTM D891–46T. Specific gravity of industrial aromatic hydrocarbons.

ASTM D855–46T. Specific gravity of petroleum sulphonates.

AERIAL SURVEY EXHIBITION

An exhibition illustrating the application of aerial survey to geology opened at the Geological Museum, London, on June 1, and will remain open for several months. The methods of producing maps and models are shown and there are numerous photographs of geological interest. The exhibition has been arranged by the companies of the Hunting Aviation Group.

Santomerse No. 1 is the title of a new booklet from Monsanto Chemicals Ltd. It gives information on this detergent and wetting agent.



Part of the first high pressure acetylene plant in the U.S.A. recently opened by the General Airline & Film Corpn. at Grasselli, New Jersey.

AUTOMOBILE DESIGN: BASIC PROBLEMS* AND CURRENT PRACTICE

By M. S. CROSTHWAITE

UNTIL about the middle of 1948 Great Britain was still producing most of its cars to designs of 1938 or earlier. There had been a little "dressing up" to prepare the way (or soften the blow, according to one's taste) for the general appearance of the 1949 car, but in mechanical design there had been no marked forward step, except for a few entirely new designs of cars built in small quantities and appealing particularly to the sports car connoisseur.

In this brief survey it will not be possible to do more than touch upon a small number of the more important factors in car design. Therefore, only the typical car of the low or medium price group, such as forms the mainstay of the British industry, will be considered.

In so doing, the contributions made to design knowledge by racing and sports cars in the past have not been overlooked. It is considered, however, that this influence is a rapidly decreasing factor. The path of racing car design has long since diverged from the main road of car design to a point far removed from everyday conditions. Indeed, the pure racing car has become almost solely an instrument of national propaganda in those countries where automobile racing flourishes.

Regarding the sports car, the definition of which would form a separate subject for examination, it would also appear that a dwindling contribution to knowledge can be expected from this source. Either it is, so to speak, a by-product of an organization or group of firms producing cars of the "everyday" type, in which case its design will follow the general trend of thought in the communal research department, or it is produced by a small firm with no research facilities, and is possibly an assembly of components obtained from specialized suppliers. In the latter case, any considerable contribution to design knowledge is likely to be the result of "inspired guesswork" by one or two people, and in the present state of the art, the scope for major improvement by these firms is small. Inspired guesswork is the essence of successful development, but the problems to be solved to-day demand not one or two, but teams of inquiring minds with the requisite material resources at their disposal. Furthermore, many of these specialist cars also exhibit a divergence from the main road of evolution, in that they perpetuate, for example, characteristics in their suspensions and riding that fall below acceptable standards for everyday travel.

The largest and most exclusive cars are again a special case in design. Their weight, potential and usable performance, and the degree of refinement expected from them present peculiar problems that demand solutions different from, and indeed sometimes opposite to, those suitable for the small and medium-sized quantity-produced car.

To define more closely a typical example of the new car of medium size and price: it will have an engine of about two litres swept volume, four cylinders, overhead valves, a four-speed gear-box, hypoid bevel final drive, independent front suspension with coil springs or torsion bars, and a rear axle located in the frame by the laminated rear springs. It will have a wheelbase of about 96 inches and will weigh about 2600 lb, with a front/rear weight distribution of 53/47 per cent.

GENERAL LAYOUT

There are good reasons, apart from

* Read before Stanlow Branch, Institute of Petroleum, *February 16, 1949.*

purely technical ones, why the combination of forward engine and rear-wheel drive is the most satisfactory compromise, in spite of the necessity for a long propeller shaft to transmit the drive. The point can perhaps be better appreciated by examining the alternative "grouped" form of layout, where the power unit and final drive form one unit. The front-engined, front-wheel drive car offers the advantages of a favourable weight distribution and an unobstructed floor for the body. Against this must be set the additional complication of the steering of driven wheels, the reduction of effective adhesive weight due to torque reaction and also weight transfer on gradients, an apparent increase in noise, and the difficulty of mounting a large engine sufficiently far forward to allow the front passengers to be placed as close as possible to the front wheels.

The principal disadvantage of the rear-engined, rear-drive car is the unfavourable weight distribution. Apart from this point, which will be referred to later, the power unit is likely to encroach upon the space within the wheelbase unless excessive overhang is permitted, and there are also complications in the control mechanisms and in the cooling arrangements.

The main objection, with the exception noted, to the "grouped" layouts is, therefore, that they encroach upon the desirable passenger space within the wheelbase. Starting then with the passengers seated within the wheelbase, what space is left for the power unit and luggage? Between the front wheels there is a space restricted in width by the necessity for providing steering lock. Nothing fits into this space so well as the in-line engine. Moreover, since the engine and gear-box account for 18 to 20 per cent of the weight of the car, good weight distribution can thus be obtained. At the rear, there is a wider space available between the rear wheels, controlled in height by the need for a rear window and in fore and aft depth by the overall length of the car. This space is well adapted for the stowage of luggage. The only mechanical component then likely to encroach upon the passenger space is the propeller shaft, which in most designs still needs some form of tunnel in the floor. Increasing use of hypoid bevel gears for the final drive has permitted a substantial lowering of the transmission line, but the incidence of another factor is likely to force a final solution to the problem. This factor is the greater length of propeller shaft called for by the forward engine position now established. For a given diameter the critical speed of the shaft in relation to whirling is inversely proportional to the length squared, and with reasonable shaft diameter the practical limit of length has already been reached in normal design. It will be evident that either a two-stage shaft with intermediate bearing must be employed, or an extension of the gear-box must be provided to bring the coupling flange for the propeller shaft as far back as possible. This second solution may meet the case of a short-wheelbase vehicle, but probably in the long run the two-stage shaft will be adopted.

There seem to be no sound technical or practical reasons for departing from the conventional layout of the automobile, but fashion and the stylist may force changes that the engineer might find difficulty in defending on technical grounds.

Ride

There are two main motions of a car body: "pitch" and "bounce". Pitch is the angular movement of the sprung mass about a transverse axis (through the centre of gravity in the ideal case), whereas bounce is the vertical displacement of the mass on its springs. In the ideal case where the centre of gravity of the suspended mass is midway between the spring supports, and the springs are

of equal stiffness (have equal static deflections), these two motions can exist separately, and the frequency is a function of the mass and the static deflection of the springs in the case of bounce, and of the moment of inertia about a transverse axis through the centre of gravity and of the static deflection of the springs and the distance between springs in the case of pitch.

In practice, such an ideal system seldom exists, and due to lack of symmetry the actual motion is always a combination of bounce and pitch, with a continuous interchange of energy between the two types of motion. If, for example, there is a great difference in the static deflection of the front and rear springs, the motion of a given point in the system ceases to follow a smooth pattern, and there is an interference or "beat" effect that may be extremely uncomfortable for the rear-seat passengers. Twenty years ago a typical car had static deflections of 2 inches at the front and $5\frac{1}{2}$ inches at the back, resulting in unpleasant interference kicks for the rear-seat passengers. The reason for the low static deflection of the front springs was the necessity for limiting angular movements of the front axle about the longitudinal axis of the car, which gave rise to undesirable gyroscopic effects to be referred to later. It was to reduce these effects to the minimum that independent front suspension became a feature of modern design, since it permits high deflection of the front springs with the minimum deviation of the front wheels from their normal plane of rotation during movements of the suspension.

With freedom to make the static deflection of the front and rear springs approximately equal, it is now possible to eliminate the interference kick and provide a "flat" ride. A typical car of the type under discussion has front and rear static deflections of $6\frac{1}{4}$ inches and $6\frac{7}{8}$ inches respectively.

There remains the question of the frequency to be employed. Frequency is closely related to amplitude in so far as the human body will tolerate large amplitudes at low frequency and small amplitudes at high frequency. In the riding of a car a figure of 80 vibrations per minute can be taken as reasonable for the bounce frequency, and this figure depends upon the mass of the suspended body and the static deflection (stiffness) of the springs. The pitch frequency, however, depends upon the moment of inertia about the pitch axis, the static deflection of the springs, and the distance between them. In nearly all practical cases this distance corresponds to the wheelbase.

The moment of inertia of the total sprung mass will depend upon the location of the various masses (engine, passengers, spare wheel, luggage, etc.) in relation to the centre of gravity. Widely separated masses increase the moment of inertia and slow down the pitch frequency, and a similar effect is obtained by shortening the wheelbase. It may be taken that the static deflection of the springs will be determined primarily by the desired bounce frequency and the permissible amount of movement of the wheels under conditions of maximum deflection.

It is found in practice that the most comfortable ride is obtained when the bounce and pitch frequencies are approximately equal. A considerable practical difficulty exists, however. Lanchester has pointed out that in nearly every case the spring separation (wheelbase) is too long, i.e., the pitch frequency is too high.

What methods are open to the designer to overcome this difficulty? There is clearly a point beyond which the wheelbase cannot be shortened, so that an increase in the moment of inertia may be necessary. This can be obtained by moving the engine farther forward, for example, but there are again limits to this method of attack, for the increased moment of inertia will also be

apparent in the horizontal plane. This may adversely affect the handling of the car, and result in sluggish response to the steering-wheel. By a combination of these two methods, however, a satisfactory compromise can generally be obtained.

It must not be overlooked that a reduction in frequency by increasing the moment of inertia may lead to the acquisition of a large amount of energy in pitching. This must be dissipated by the dampers, and due allowance must be made for this in their selection. It is no exaggeration to say that upon the selection of damping characteristics depends the success of the modern suspension ideal. In the writer's opinion some of the present-day cars are approaching the limit in short wheelbase and high moment of inertia, and any further attempt to improve the ride by these convenient methods is likely to impair handling characteristics, particularly in conditions of gusty side winds at high road speeds.

Handling

This term covers every aspect of car behaviour other than its riding characteristics and performance in respect of acceleration, braking, etc. It is only comparatively recently that any serious attempt has been made to co-ordinate all the factors involved, and no discussion can be entered into without acknowledgment to the work of Evans and Olley, which since 1932 has resulted in the publication of many papers on the subject with consequent benefit to all automobile engineers. The following remarks summarize the main features of this work.

All problems of steering and handling are fundamentally dependent on tyre behaviour. Fig. 1 shows the three most important tyre characteristics that affect steering. At (*a*) is shown a tyre subjected to a side force F (e.g., centrifugal force due to the car following a curved path). This force is balanced by a force F_1, termed the cornering force, acting at the contact area between the tyre and the road. Note that the force F_1 acts at a point behind the centre of the contact area, giving rise to a couple F_1x termed the self-aligning torque of the tyre. A further characteristic of the tyre is that in order to develop the cornering force F_1, it must drift sideways in the direction of the applied force F, so that the direction of the resultant motion of the tyre makes an angle ϕ with the plane of rotation of the tyre. This angle is known as the slip angle.

At (*b*) is shown a cambered wheel, rotating in a plane at an angle θ (the camber angle) with the vertical. In this

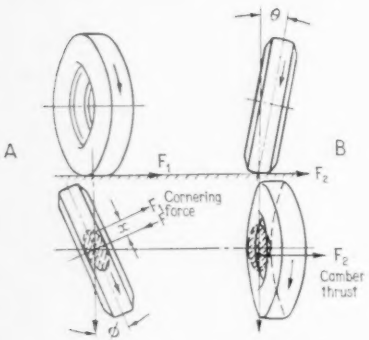


Fig. 1

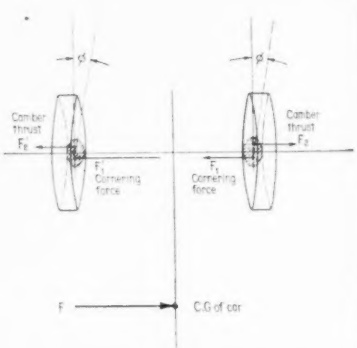


Fig. 2

condition the wheel will tend to follow a circular path, and if constrained to follow a straight-line path a side force F_2 is present, acting at a point ahead of the centre of the contact area. This gives rise to a camber torque, but for all practical purposes it may be neglected. The camber thrust, however, is important, since it may add to, or subtract from, the cornering force (Fig. 2), and with most systems of independent suspension the camber angle varies as the car rolls.

From these three characteristics of a tyre, viz., cornering force, self-aligning torque and camber thrust, the following general conclusions have been formed after practical test:

1. At small slip angles the cornering force is proportional to slip angle, but becomes relatively smaller at higher slip angles.

2. Cornering force increases with load up to maximum, and then decreases, the rate of change increasing with the slip angle. The implications of this under conditions of the car rolling are of great importance, and they strongly influence the design and location of a stabilizer, when fitted.

3. The self-aligning torque increases with slip angle up to a maximum, and then decreases. Olley claims that at large slip angles of 12° to 15° the torque *reverses*, but this is not accepted by all investigators.

4. The self-aligning torque increases rapidly with load, particularly at higher slip angles.

5. Camber thrust increases with load, but not proportionally at high loads.

6. Camber thrust increases proportionally with camber angle.

Over- and Understeer

Fig. 3 shows a car nominally following a straight course AB. If it is now subjected to a side force F the reactions F_1 and F_2 at the front and rear wheel contact areas result in the development of slip angles ϕ_1 and ϕ_2. If the rear slip angle ϕ_2 is greater than the front slip angle ϕ_1, the car will follow a curved path A_1, and centrifugal force augments the original disturbing force. This is the condition of oversteer, which becomes rapidly worse as the car speed is increased.

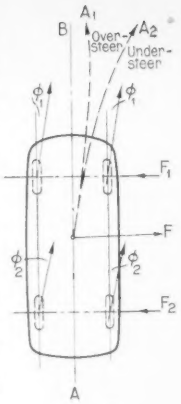


Fig. 3

If, however, the front slip angle ϕ_1 is greater than the rear slip angle ϕ_2, the car follows the curve A_2, and the centrifugal force opposes the disturbing force to a degree varying as the square of the velocity. This is the condition of understeer, and, by inference, the higher the speed, the more tenaciously will the car oppose lateral disturbances. The oversteering car, on the other hand, becomes unstable beyond a certain speed, and only remains controllable by virtue of the alertness of the driver in taking advantage of the inertia of the car to keep it broadly on its course.

When taking a corner an understeering car attempts to follow a wider radius than theoretically ideal geometry would suggest, and needs to be "pulled in" by the driver. An oversteering car, on the other hand, attempts to "nose-in" on a corner, and the driver must "pay back" on the wheel when the car has assumed its ultimate attitude after the initial transition period.

Summing up, it may be said that an understeering car is fundamentally stable, but if the characteristic is pronounced the car may prove tiring to handle on a twisty road. The oversteering car is inherently unstable, but if the characteristic is not highly developed it may be a "handier" vehicle in similar circumstances. However, the potential

performance of even medium-sized cars nowadays suggests that understeer is the only safe aim for the designer, otherwise an indifferent but venturesome driver exploring the full capabilities of his car may find himself in difficulties. With certain cars 60 m.p.h. is quite fast enough to pass the point when directional instability is kept in check solely by the driver's sense of balance.

Space does not permit reference to the many subsidiary problems involved in tyre behaviour, but the effect of rolling of the car must be mentioned. In all suspensions where the front wheel camber alters as the car rolls, there is a steering effect due to the variation in camber thrust. Moreover, the resisting couple is supplied by the wheels in proportion to the roll stiffness of the front and rear suspensions. Considering the outer wheels of a car turning a corner, it will be obvious that they will carry a greater load, and if too much of this is taken by the rear wheel, oversteer will result due to its increased slip angle. Similarly, if a high proportion of the additional load is taken on the front wheels, the car will understeer. For this reason, in many cars where a stabilizer or anti-roll bar is employed, it is placed at the front. There are ways, however, of tackling the problem if for other reasons it is desirable to place the stabilizer at the back. Thus by offsetting the rear axle from the centre of the rear springs and by inclining the springs downwards towards the front, the axle may be made to skew slightly under rolling conditions, thereby introducing "understeer geometry" to oppose the oversteer effect of the increased load on the outer tyre and the decreased load on the inner tyre.

At this point the principal objection to the rear-engined car may be referred to. This is the inevitable concentration of weight on the rear wheels, resulting in pronounced oversteering tendencies if the same size of tyre is used front and rear. Although geometrical understeer of the suspension might be carried far enough to counteract the weight factor, the tyres would be operating at such high slip angles that the limit of cornering force would be reached at quite moderate accelerations of the mass of the car.

Some of the most interesting effects of tyres on steering have yet to be investigated. The foregoing remarks refer to the steady state, whereas in practice the car is constantly subjected to changing forces. It is to the evaluation of the transitional state that current research is directed.

Suspension

The reasons underlying the adoption of independent front suspension have been briefly discussed already. To recapitulate, they comprise the great reduction in gyroscopic effects of the front wheels due to smaller deviations from their planes of rotation during movements of the suspension, and the interposition of the mass of the car between the front wheels. Direct coupling of wheel motions through the medium of a rigid axle is eliminated. Thus it becomes possible to use greater wheel movements and therefore softer springs.

Most independent front suspensions use wishbones and coil springs or torsion bars. Laminated springs survive in a few layouts, but in spite of the fact that they can be employed not only as springs but as structural members, their relatively high and variable interleaf friction (unless well maintained) is a disadvantage. A suspension system is very sensitive to small amounts of friction, and the effect on steering may be far from negligible. Thus, if friction prevents the sprung mass of the car returning to its normal position after rolling, there will be a drift of the front wheels owing to the changed camber angle.

By far the most popular type of independent front suspension layout is that embodying wishbones and coil springs.

It is compact, relatively cheap, and can be arranged so as to have its bearings adequately spaced to resist brake torque reactions without sustaining excessive loads. The lengths of the upper and lower members are commonly determined so that the point of contact with the road moves substantially in a vertical line as the wheel rises and falls, thereby maintaining the track constant. This eliminates tyre scrub, although in actual fact the importance of this factor has probably been exaggerated. Some change in camber occurs, although not enough to cause serious gyroscopic effects, but the location of the joints in the steering connexions is of the greatest importance. The centre about which the outer track rod swings must coincide with the virtual centre of wheel movement if "fidgeting" at the steering-wheel is to be eliminated.

Examples of the Dubonnet type of suspension are still to be found, and the trailing link type has recently gained a number of adherents. These suspensions, although having certain geometric advantages over the wishbone type, present difficulties in obtaining an adequate span for the bearings of their pivot pins. Rapid wear has been experienced on some examples.

The case for independent front suspension is undoubtedly proved, but at the rear of the vehicle there appears to be little benefit to be obtained when the mechanical complication is considered. In any case, the great value of independent suspension in reducing the gyroscopic *effects* of the front wheels is not applicable to the rear wheels, which are not mounted on swivel pins. The gyroscopic *forces* when the rear wheels are displaced from their normal plane of rotation are, of course, present, but since the wheels are not permitted to pivot about swivel pins the *effects* are not of any consequence. Furthermore, any type of independent rear suspension is likely to introduce a pronounced oversteering characteristic unless considerable "understeer geometry" of the system is provided. The most widely used type of independent rear suspension is the swing axle, although parallel action and trailing link types are also employed.

Regarding orthodox layouts of the rear suspension, the laminated spring is still the most common form of suspension and axle location. There is already a tendency in the U.S.A. to employ coil springs, necessitating separate means of locating the axle in the frame. This is commonly done by using a torque tube to give fore and aft location, with a transverse link to hold the axle against side movement. Incidentally, the handling of a car with laminated springs is generally improved by the addition of a transverse link, particularly when rubber bushes are employed in the spring eyes and shackles.

Engines

Only two or three trends in engine design can be mentioned here. The marked swing away from side valves appears to be inevitable as specific outputs increase, and b.m.e.p. of 130 p.s.i. become common. The revival of the inlet-over-exhaust layout is noteworthy, and offers the possibility of obtaining a large inlet-valve diameter and adequate cooling of the exhaust-valve seat. On the question of general engine cooling, there is a move towards restricting the forced circulation of cooling water to the cylinder head, often in conjunction with an internal gallery from which jets are directed on to the exhaust-valve seats, sparking-plug bosses, and other local hot spots. Around the cylinder bores the water is under no positive influence to circulate other than by thermal effects. In consequence, there is a more even temperature throughout the jackets and distortion is minimized. A thermostat whereby the radiator is by-passed during the warming-up period is now more generally employed.

Perhaps the most obvious feature of the new cars of medium size and price

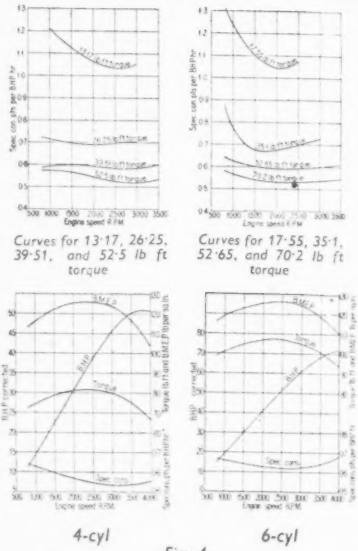
is the return to favour of the large four-cylinder engine, made possible by the better understanding of flexible mounting technique. Except when pulling strongly at low speeds, there is little cause for dissatisfaction with the smoothness of these engines. Owing to the presence of unbalanced secondary forces the problem of vibration isolation is a little more difficult, but some of the best examples of the type give no indication of undue disturbance.

Undoubtedly the four-cylinder engine has economic advantages over the corresponding six, both in the outlay for plant for its production and in running costs. Reduced to its simplest terms, there is a smaller area of machined surface, the overall length and weight of the engine are smaller, and the jacket losses are smaller owing to the lower surface/volume ratio of the cylinders. More important, however, than the last point is the matter of mixture distribution. Here the four-cylinder engine scores heavily, in that its inlet manifold design is inevitably more simple, and good mixture distribution can be obtained. Fig. 4 shows the specific fuel consumptions of two similar engines, one a four and the other a six. The part-throttle curves agree closely, but at full throttle the four-cylinder engine is distinctly superior.

With the change in the system of taxation from one based on engine dimensions to the flat rate system, stroke/bore ratios are decreasing from about 1·45 to 1·2 or even less. The advantages to the designer are considerable, easing the provision of adequate valve area and permitting higher engine speeds for a given piston speed, an important gain in attaining a high cruising speed with a medium-sized engine.

The dominating influence of fuel supplies renders discussion of higher compression ratios somewhat academic so far as British cars are concerned. Such information as is available on American developments suggests that there are still substantial gains to be obtained in specific output and fuel economy by raising the compression ratio, and two basically new engines are in production, designed to accommodate any possible improvement in fuel quality for some years to come.

A good deal of publicity has been given to devices intended to inject small quantities of anti-detonant fuel under full-throttle operation, normal operation being on lower-grade fuel. It seems



Curves for 13·17, 26·25, 39·51, and 52·5 lb ft torque

Curves for 17·55, 35·1, 52·65, and 70·2 lb ft torque

4-cyl

6-cyl

Fig. 4

doubtful whether they can find lasting favour in everyday use, since they introduce an additional burden on the owner in the matter of replenishment.

Gear-boxes

Notwithstanding the popularity of semi-automatic transmissions in the U.S.A., the conventional clutch and synchromesh gear-box remains virtually unchallenged on British cars. This is largely a matter of cost, and bearing in mind the ease of manipulation of the synchromesh gear-box, there seems to

be every justification for its use. It is also probably the lightest solution, and with improved power/weight ratios the amount of gear changing necessary is steadily decreasing. All semi-automatic and automatic transmissions are relatively complicated, and bearing in mind that the small car needs a gear-box covering a range of torque ratio of about 4·5 : 1 as against 2·6 or 2·7 : 1 in the case of large cars, the difficulties are clear. With a wider torque ratio range a greater number of intermediate steps becomes desirable, and the mechanism is accordingly complicated. Perhaps the most generally satisfactory solution is the three-speed gear-box with a "kick-down" overdrive.

The hydrodynamic torque converter, in spite of its superficial attraction, demands a good power/weight ratio if it is to combine good car performance with economy. In its best known form, the Buick Dynaflow transmission, the maximum torque ratio is 2·25 : 1, and an auxiliary gear-box is incorporated in the system.

In general, the transmission problem may be summed up thus—no gear-box can take the place of a good power/weight ratio.

Miscellaneous Components

Regarding rear axle design there is little that calls for comment other than the increasing use of hypoid gears in the interests of a low transmission line. An incidental advantage is the stronger tooth form of the pinion.

Braking systems are undergoing steady but not spectacular development. They fall generally into two classes: hydraulically operated front and rear, or with hydraulic operation at the front and mechanical operation at the rear. In few cases can the handbrake be generally commended, since it is often operated by an inadequate lever, occasionally supplemented by a further handicap in the form of a flexible cable led along a tortuous path. As an aid to driving, the handbrake is virtually dead.

An interesting development is the Girling hydrastatic brake. In this system lost motion is reduced to a minimum, and a part of the shoe is in constant contact with the drum. The resultant slight drag appears to have no appreciable ill-effect on rolling resistance.

One further point deserves mention. This is the increasing use of integral construction of the body and frame. It has advantages in increasing the stiffness of the structure and results in economy of weight by a better distribution of material. As technique in the repair shop advances, the objections to it on the score of expense incurred by accidental damage recede. Of greater moment, perhaps, is the problem of rust-proofing, but here again the advance in protective treatments is steadily being maintained.

RUST PROOFING TOOLS

A special chemical called V.P.I. (Vapour Phase Inhibitor), has been developed by Shell to protect tools, engine parts, fine instruments, and other iron or steel articles from rust. Ordinary wrapping paper, coated on one side with V.P.I., a white crystalline stable organic compound, is used as a packing for metal articles. The chemical slowly vaporizes inside the packing, thus neutralizing the corrosive action of oxygen in the air.

V.P.I., it is claimed, will help cut packaging costs for manufacturers, since its use will obviate the need for protective coatings of oil or grease on metal articles. A further advantage is that steel products containing non-metallic components, which are adversely affected by oils and greases, may generally be safely protected with V.P.I.

V.P.I. is odourless, non-poisonous and clean to use, and is currently available to potential users throughout the world.

PETROLEUM IN PARLIAMENT

Air Lift Petrol

The average monthly consumption of petrol by British aircraft on the Berlin air lift during the past three months was 9140 tons, said the Secretary for Foreign Affairs in a written answer on May 9.

Burning Oil

The Minister of Fuel and Power said, on May 16, that he had received proposals for marketing a better quality burning oil, and was discussing them with the representatives of the petroleum industry.

Leeward Islands

Questioned again as to underwater boring for oil on the coast of the Leeward Islands, the Secretary of State for the Colonies said in an oral answer on May 18 that the inquiries mentioned by him on April 6 (*see page* 144) were not completed. Until further surveys were made he could give no information about costs. The project was an immediate one, but a great deal of investigation was required. In reply to a further question, he said that there had been no geological survey of the islands.

U.K. Refining

Speaking in the Committee Stage of the Civil Estimates 1949–50, the Minister of Fuel and Power said, in reference to British refining: "The latest information I have got is that this year we hope that the throughput of the refineries here will be over 6,000,000 tons compared with about 3,500,000 tons in 1948, which is a pretty substantial increase. As I think hon. members know, we hope that in the course of the next two, three, or four years the output will rise to about 20,000,000 tons. That is the refinery programme."

Tankers

In a written reply on May 31, the Parliamentary Secretary to the Admiralty said: "Oil tankers under construction for British owners at the end of April, 1949, totalled 330,750 gross tons. Comparable figures at the end of April, 1948, were 277,870 gross tons. The tankers required for the immediate future needs of this country are provided for and it is expected that British owners will continue to build up and modernize their fleets to match the requirements of the world's seaborne oil trade."

I.P. GOLF MEETING

A very enjoyable golf meeting was held at Coombe Hill on May 31.

The weather was most kind, and the golf surprisingly good, considering that this very tricky and alarmingly wooded course was strange to all but one of the competitors.

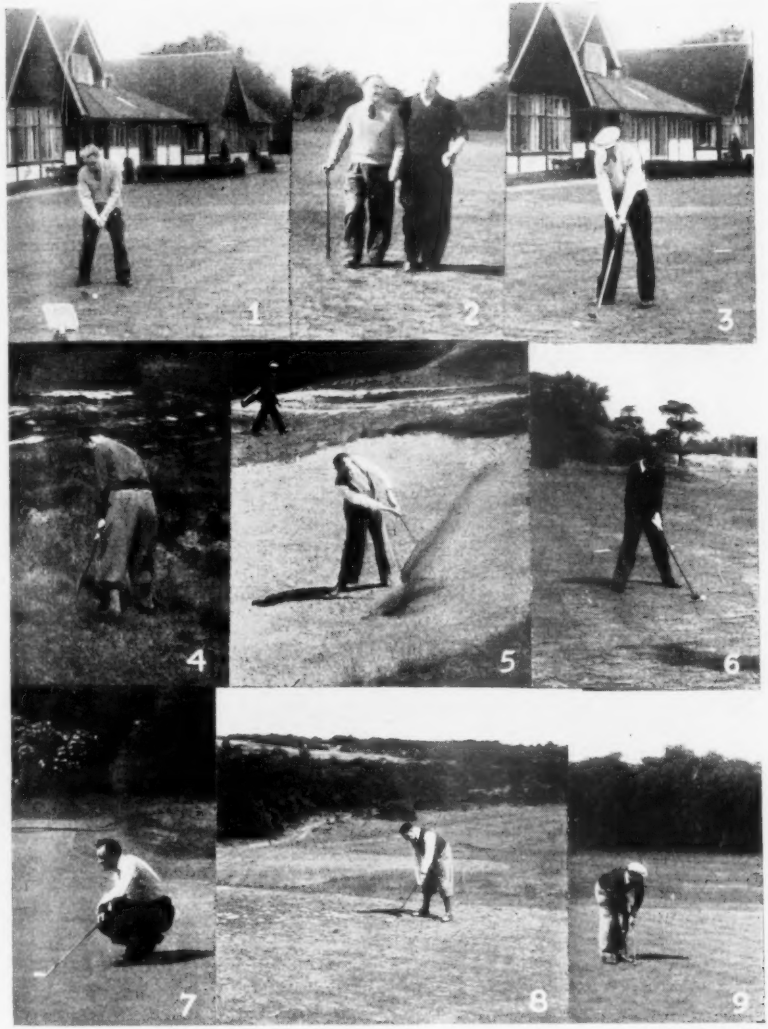
The Bogey Competition in the morning was won by T. H. J. A. Jones (hcp. 2), from the South Wales Branch, who went round in a par 72, to finish 2 up. E. C. Tickle (hcp. 16) was second with all square, and D. A. Hough (Scratch) third with 2 down.

The President (Mr E. A. Evans) delighted everyone by turning up to have lunch with the competitors, and afterwards a fourball stroke play competition was held, which resulted in a tie between L. W. Perkins (+ 1) and A. G. Eadie (4), and E. C. Tickle (16) and C. Ratcliffe (8), both sides finishing in 69 net.

Tea and prize-giving at 5.30 p.m. ended a very pleasant day, and, it is hoped, one that will be repeated.

Slush Pumps and Fluid End Parts for Slush Pumps are the titles of the latest bulletins (Nos. 349 and 357 respectively) of the *National Supply Export Co.*

AT THE I.P. GOLF MEETING



[Photos by G. Sell

The grandeur of Coombe Hill Golf Course is well illustrated in (8), where E. J. Sturgess is seen approaching the 4th hole, while the magnificent club-house is partly seen in (1) with J. R. Thompson and (3) the general secretary of the Institute preparing to start off. In (4) we see N. E. F. Hitchcock in the rough, while in (5) J. L. Murray gets out of trouble in one. A. G. Eady is addressing the ball in (6), and in (7) J. N. Atkins studies the line of a putt. In (9) L. W. Perkins holes a four-yarder at the 6th. In (2) we see J. R. Thompson and J. S. H. Don making their way in.

COUNCIL COMMENTARY

TWENTY-TWO members or about half the potential strength of the Council assembled on May 11, apologies having been received from the rest. This is a reasonably good attendance considering the various duties and responsibilities of members of the Council.

The President welcomed as new Council Members Messrs H. S. Gibson, A. J. Goodfellow, N. E. F. Hitchcock, E. J. Horley, and J. C. Hancock.

The previously circulated minutes having been tabled and approved, matters arising from them were disposed of.

The President reported that letters of thanks had been sent to Messrs A. Beeby Thompson, A. T. Beazley, and R. R. Tweed on the termination of their services on the Council; also that Mr Victor Butler, who was at present abroad, was considering the question of an advisory committee for lubricating oil.

Discussion of the letter from Trinidad Branch dealing with membership mentioned in previous notes, was deferred until after the visit of the Honorary Secretary of the Trinidad Branch, who is expected in England during the summer, and would be invited to attend a joint meeting of the By-Laws and Election committees if such could be arranged.

A report of the Election Committee was approved and satisfaction expressed at the lengthy list of the additional Member-Companies, and in particular the increased subscriptions as a result of second thoughts.

The Election Committee were asked to make recommendations to deal with the question of issuing Certificates of Membership to Members and Member Companies.

Mr Hyams stated in dealing with the financial affairs of the Institute, that whilst the target set for Member-Companies' subscriptions had been passed, there was still need of a further £4000 or £5000 this year to avoid drawing on reserves, and that the fact should not be lost sight of that next year's income from individual members was uncertain, as there might be resignations following the increase in subscription rates. He was optimistic that the necessary money would be forthcoming from the major companies, and also that we could consider the raising of a Building Fund to purchase our own building, since the annual expenditure would be greatly reduced if this could be done, the high rental now being a disproportionately large item of our expenditure.

The Publications Committee presented a report through Prof. Garner who stated that the first meeting of the Organizing Committee of the Oil Shale and Cannel Coal Conference was to be held in Edinburgh on May 19. He also announced an increase in paper allocation which might enable a larger *I.P. Review* to be considered. Mr Dewhurst took the opportunity to remind the Council that much of the credit for this increased paper allotment was due to pressure by the Parliamentary and Scientific Committee.

The Chairmen of various Council Committees were nominated as follows, subject in some cases to confirmation being obtained from the individuals concerned, it being left to the Honorary Secretary and the nominated chairmen to submit proposals for the various Committees for 1949–50 to the Council for consideration at the next meeting:

Aviation Products	*F. L. Garton*
Awards	*H. C. Tett*
Benevolent Fund	*A. E. Dunstan*
Branches	*J. A. Oriel*
By-Laws	*V. Biske*
Education	*E. Thornton*
Election	*M. A. L. Banks*
Engineering	*E. J. Sturgess*
Finance	*H. Hyams*
House	*S. J. M. Auld*
Liquid Fuel Installations	*F. H. Garner*

Publications	*F. H. Garner*
Public Relations	*C. T. Brunner*
Research	*F. Morton*
Standardization	*E. A. Evans*

The British National Committee of the Third World Petroleum Congress was nominated by the Council as the result of a letter received from the Dutch Organizing Committee, the Committee to be as follows:

Col. S. J. M. Auld (*Chairman*)
T. Dewhurst
H. C. Tett
H. Hyams
Prof. F. H. Garner
H. S. Gibson
C. Chilvers (*Hon. Sec. of the Institute of Petroleum*)

Col. Auld reported that an exhibition had been proposed by the Council of British Manufacturers of Petroleum Equipment to be held in London in 1951 during the London Exhibition. He stated that after discussion with the major oil companies, the project might be expanded to become an exhibition of oil, and if backed by the Institute of Petroleum would probably receive the support of the oil industry, though it was considered that any approach to the industry should come from the Institute. It was left with Col. Auld to continue the tentative discussions, and in conjunction with the President to prepare a letter for the oil companies, it being agreed in principle that the holding of this exhibition in London during 1951 was a good thing.

The President also read a letter stating that the Hydrocarbon Research Group was glad to welcome the Manchester Oil Refineries Ltd. and Petrochemicals Ltd., who had offered to join the Hydrocarbon Research Group.

The General Secretary reported on behalf of the Benevolent Fund Committee, that an annual grant had been made to cover the education of a child of a member of the Institute who had died last year in Trinidad.

STANLOW BRANCH

Officers of the Stanlow Branch of the Institute for 1949–50 are:

Chairman: C. D. Brewer
Hon. Secretary: V. Biske
Hon. Treasurer: A. G. V. Berry
Committee: J. G. Hancock
N. Kendall
F. Mackley
J. S. Parker
W. T. T. Wilcox

WORLD POWER CONFERENCE

Their Royal Highnesses the Princess Elizabeth and the Duke of Edinburgh have graciously consented to extend their patronage to the Fourth World Power Conference, to be held in London July 10–15, 1950.

As already announced, the theme of the Conference will be "World Energy Resources and the Production of Power". Over forty member countries are expected to send delegates.

FULLER'S EARTH

Production of fuller's earth in the U.S. during 1948 totalled 342,081 short tons, a 4 per cent increase over the 1947 total of 329,068 short tons. Mineral oil refining took 194,225 tons (57 per cent of total) and rotary drilling mud 22,608 tons. Average value rose from $14·16 per ton in 1947 to $15·42 in 1948.

Whessoe Ltd., of Darlington have concluded an arrangement with Shand & Jurs of Berkeley, California, to manufacture and sell S & J tank fittings to the petroleum industry.

SPECIAL GENERAL MEETING

The following changes in the By-Laws of the Institute of Petroleum were approved at the Special General Meeting held on May 11, 1949:

(1) That By-Law number 37 be altered in the following manner:

By substituting for the annual subscription to be paid by Members, Fellows, Associate Members, and Associate Fellows the following revised subscriptions, namely:

Members	£4	4	0
Fellows	£4	4	0
Associate Members	£3	3	0
Associate Fellows	£3	3	0

(2) That By-Law number 37 as amended, and as set out below, is hereby approved and adopted as part of the By-Laws of the Institute, in substitution for and to the exclusion of the existing By-Law number 37.

REVISED BY-LAW 37

"*The following shall be the Annual Subscription to be paid for the classes of membership named:*

Hon. Members and Hon. Fellows	Nil		
Members	£4	4	0
Fellows	£4	4	0
Associate Members	£3	3	0
Associate Fellows	£3	3	0
Member-Companies Minimum	£10	10	0
Collective Members	£10	10	0
Affiliated Members As may be determined by Council			
Student Members	£1	1	0

The Council shall have the power to reduce or to remit the Annual Subscription of a Corporate Member who has attained the age of 60 and who has retired from active participation in the petroleum or allied industries, or of any Corporate or Non-Corporate Member who shall have become temporarily unable to continue the subscription due from him."

(3) That the amended By-Law as in (2) above shall become effective on January 1, 1950.

A MESSAGE FROM THE PRESIDENT

It must be clear to all our members that the constantly rising costs of everything must have affected the finances of the Institute. It must also be clear that the ever-expanding work which the Institute has undertaken cannot be done without some financial burden. The work and responsibilities of the Institute have called for increased office accommodation, and an increase in staff. These few facts must be obvious and should not call for special comment.

I feel, however, that a few words of explanation should be given to those members who were unable to attend the Special Meeting which was held on May 11, when it was agreed that subscriptions should be increased. None of us welcome being asked to pay increased sums for our privileges and needs. Your Council has been very conscious of this fact. Nevertheless, it has been compelled to find added sources of revenue. It is aware that some of the work which it sponsors is not chargeable directly to a professional body, consequently some financial relief should come from industry. I am glad to say that our invitation for Member Companies has received a reasonably satisfactory response, and that the income from this source is definitely helpful. But, it is impossible to continue to give to our Corporate Members all the privileges which they at present enjoy without some increase in subscriptions. What that added subscription should be has been the subject of extremely careful consideration, and I hope that the conclusion which the Council reached will be accepted and supported by our members.

The Institute of Petroleum is now a

very powerful body, and it would be a pity to relinquish any of its responsibilities, and consequently its power, through the lack of financial support. I feel sure, therefore, that our members will understand and continue to give the Institute the support which it has always received.

E. A. EVANS (*President*)

FAWLEY REFINERY

Work has now begun on the construction of the oil refinery, being built by Anglo-American Oil Co. Ltd., at Fawley, 15 miles south-east of Southampton.

Announcing this, David A. Shepard, chairman of the company, said that the project was an important contribution to the programme, outlined in the Government's Economic Survey for 1949, to increase the oil-refining capacity of the United Kingdom. Important savings in dollar expenditure would result from increased shipments of crude petroleum from the Middle East for refining at Fawley instead of importing more costly refined products.

The plant is expected to cost approximately £37,500,000 and to take about three years to complete. Its site covers some 970 acres; and ultimately about 2500 people will be employed as compared with 900 at the existing refinery.

At a press conference, Mr Shepard said that the plant would consist of primary distillation in two pipe stills, each of 60,000 brl/day throughput one operating under vacuum and the other at atmospheric pressure. A fluid catalytic cracking unit, designed by Standard Oil Co., would operate on a gas/oil feed to produce cracked naphthas, and there would be a large Edeleanu plant for the treatment of kerosine. In addition there would be the necessary finishing plants.

A special feature of the refinery would be the mechanical workshops for maintenance of the plant, with the corresponding warehouse facilities. Workshops and warehouse were to be contained in one large building approximately 800 ft by 180 ft.

Input would consist of crude oils from the Middle East—from Iraq, Iran, and Kuwait—and output of finished products would, subject to market requirements, be of the following order:

	Brl/Day	*Tons/Yr*
Gasoline, naphtha, and white spirits	42,500	1,800,000
Kerosine	6,000	290,000
Diesel fuel and gas oil	14,000	700,000
Light fuel oil	6,000	300,000
Bunker fuel	30,000	1,800,000
Asphalt	3,500	200,000

It was intended that over 90 per cent of the products would be distributed from the refinery by ocean-going tankers. In order to cope with incoming and outgoing cargoes—which would average about one T.2 tanker in each direction per day—special consideration was being given to docking facilities, and it was expected that berths for four or five of the largest size of tanker visualized would be available.

PERSONAL NOTES

Prof. F. H. Garner, O.B.E., F.Inst.Pet., and *J. A. Oriel*, C.B.E., F.Inst.Pet., are among the membership of a committee recently set up by the D.S.I.R. to review the needs for research in chemical engineering and the extent to which they can be met by existing research establishments.

Frank C. Tiarks has resigned from the board of Anglo-Iranian Oil Co. Ltd., and *William Johnston Keswick* has been appointed a director.

Ralph P. Bolton, F.Inst.Pet., has been appointed Standard Oil Co. (New Jersey) representative for affiliates engaged in producing, refining, and marketing operations in Italy.

S. WALES BRANCH

At their meeting on May 6, the South Wales Branch of the Institute was addressed by W. H. Thomas on the subject of "The examination of petroleum". The speaker dealt with the relation of the analytical laboratory to the refinery and its auxiliary services to development and research and to "sales" requirements. In a very interesting talk, illustrated with lantern slides, he discussed the following:

The Laboratory—Requirements for routine, development and research work, space, layout, etc.

The Apparatus—Routine and specialized equipment.

The Chemist or Analyst—Selection of right type, qualifications, experience, training, etc. Report writing and control of staff.

Test Methods—Standard Methods and their application and justification for modifications for refinery use. Analytical Research.

Results—Reporting, checking, recording and routine control. The significance and utilization of test results.

In the discussion which followed, Mr Thomas elaborated on points arising from the talk and dealt with all questions in a capable manner.

M.P.s VISIT ENGLISH OILFIELD

Eleven Members of Parliament visited the D'Arcy Exploration Company's oilfield at Eakring, Nottinghamshire, on May 25. The tour was organized by the Petroleum Information Bureau as one of a series to enable Members to see at first hand the working of the petroleum industry in Great Britain.

The party arrived at midday and were welcomed by W. Woodcock, manager, English drilling and production, of the D'Arcy Exploration Company, and by senior staff. They were entertained to lunch and afterwards saw the laboratories, production plant, and wells, and watched a drilling rig in operation.

At the conclusion of the tour T. J. Brooks (*Rothwell*) moved a vote of thanks, in which he expressed the keen interest of the party in all they had seen. The vote was seconded by Major W. F. Vernon (*Dulwich*). Other members of the party were E. A. Hardy (*Salford*), Edward Porter (*Warrington*), J. D. Murray (*Spennymoor*), David Griffiths (*Rother Valley*), H. B. Taylor (*Mansfield*), H. Neal (*Clay Cross*), G. Deer (*Lincoln*), C. F. Grey (*Durham*), and H. White (*Derby*).

THE PURPOSE AND EVOLUTION OF OIL FUEL SPECIFICATIONS

By C. W. G. MARTIN (Fellow) and D. R. BAILEY (Assoc. Fellow)

Object of Specifications

It is perhaps as well to begin by stating why oil fuel specifications are deemed necessary at all.

A specification has two distinct functions to fulfil:

(i) to control the quality of the product as manufactured;

(ii) to ensure the continued supply of a reasonably constant grade to the customer.

Generally speaking, the same specification cannot fulfil both functions (that is, be both a manufacturing and a marketing specification). In order to guarantee the latter, the refiner must often work to closer limits in his manufacturing specification, or even stipulate items which do not appear in the marketing specification at all.

"Specification" or "Analysis"?

The term "specification" as used throughout this article has its literal meaning of something which is stipulated or specified (that is, it consists of rigid maximum and/or minimum limits). It is therefore quite different in form and purpose from the indication of approximate properties which, for convenience, is usually termed an "analysis" or "inspection". Thus, the particular set of results emanating from a laboratory examination of an oil fuel sample can be appropriately described as an "analysis". If, however, a customer, using these figures as a guide, proceeds to lay down the limits to which he is prepared to go in accepting future supplies of a similar product, the new set of figures may be properly termed a "specification".

What we Require of a Specification

A little thought will show that a specification must be *reasonable*, *useful*, and *economic*. It will perhaps be as well to explain what we mean by these three headings.

(*a*) *A specification must be reasonable.* It would normally be unreasonable, for example, to stipulate limits such that the test results required could be obtained only by supplying a product of non-petroleum origin. It would be equally unreasonable to insert requirements having no technical importance, or which demanded closer precision than is normally possible in commercial testing, or which ignored the Customs regulations in the country concerned.

To take an extreme example, since in most countries oil fuels are manufactured to a minimum closed flash-point of 150° F, it would generally be unreasonable for an individual buyer to stipulate flash-points of, say, maximum 140° F for his oil fuel products.

(*b*) *A specification must be useful*, i.e., it should serve some obvious purpose and include only such items as contribute to its usefulness as a whole. Normally, for example, one would not expect to see tests like colour or octane number specified for under-boiler fuel oil!

(*c*) *A specification must be economic*, i.e., it must not be needlessly restrictive. There is a distinction between this and the requirement that it must serve a useful purpose (see (*b*) above). For example, very good reasons sometimes exist for requiring that the sulphur content of a fuel oil for a particular purpose should not exceed, say, 1 per cent. Segregation of such a grade might entail some expense. Such expense would, however, be greatly increased if for no adequate technical reason the buyer suddenly demanded that the sulphur content should not exceed 0·1 per cent.

Similarly, a buyer requiring fuel oil for ordinary under-boiler purposes is

generally indifferent to all but a few points of specification, the most important usually being the viscosity. He is thus able to use satisfactorily the cheapest available oil fuel grades. Should he demand that the fuel must also have, say, a negligible asphaltene content, then the extra cost involved in either reprocessing the fuel or delivering an entirely different grade at a higher price would normally make the proposition quite uneconomical.

Means of Arriving at a Specification

In drafting oil fuel specifications, recourse is made to various standard tests of a chemical, physical, or mechanical nature which have been carefully developed over many years by the petroleum industry. Although many of these tests are empirical in nature, they are, generally speaking, repeatable within narrow limits if the strictly specified testing technique is closely followed.

Characteristics of Oil Fuels

The characteristics of a particular product depend, firstly, upon the crude petroleum from which it is obtained; secondly, upon the method of processing the crude or the "raw" product; and, finally, upon the subsequent handling of the finished article. Thus, the natural characteristics of, say, a highly paraffinous crude will be reflected to varying degrees in the properties of the distillates and residues obtained from it; but these natural characteristics may be considerably modified according to the subsequent refinery treatment. The possibility of contamination during transportation or storage must also be taken into account.

Control of Quality

Irrespective of the grade concerned, the properties comprising an oil fuel specification must ensure that the product is:

(*a*) reasonably clean (that is, free from extraneous contamination);

(*b*) capable of being stored, handled, and used under conditions which will prevail;

(*c*) suitable for the particular application desired.

These desiderata imply that we are fully acquainted with the various test methods and their application, accuracy, and repeatability.

Selection of Tests

The laboratory tests chosen when compiling a fuel specification should not be selected haphazardly but according to a definite scientific plan based upon the use for which the product is intended and the specific information yielded by each test. Overlapping of information (that is, specifying a multiplicity of tests reflecting much the same characteristic) should be avoided.

(*a*) *To control cleanliness* and freedom from contamination, restrictions must be placed upon the water content, sediment, and (sometimes) ash content of the fuel.

The presence of water may promote combustion difficulties and, if in excess, prevent combustion altogether; it may also lead to the formation of undesirable emulsions or sludges which may render the fuel wholly or partly unusable. Moreover, the customer expects to buy oil and not water! The actual limits to be placed upon water content will depend upon the grade and application of the fuel concerned. More than 1 per cent of water may occasionally be permitted with heavy residual fuel oils, but much closer limits are applied in the case of gas oils and the higher quality distillate diesel fuels.

Solid material, which may be inorganic (like rust, sand, etc.) or organic (e.g., carbonaceous and fibrous material), may also contaminate the fuel and is collectively termed "sediment". With light gas oils, more than a trace of sedi-

ment is undesirable: with heavy bunker fuels, up to 0·25 per cent (the limit prescribed by the so-called "Bunker 'C' Grade" fuel oil specification) is usually accepted.

The amount of incombustible material remaining after the fuel has burned (termed "ash") should also be as low as possible. The ash may partly arise from organo-metallic compounds naturally existing in the oil, but is augmented by rust, sand, etc., present as filterable sediment. Furthermore, salt-water contamination may also increase the ash on account of the incombustible solids dissolved in the water. For gas oils and the higher quality distillate diesel fuels, a maximum ash content of 0·01 per cent is generally necessary. Heavy fuel oils usually have considerably higher ash contents, though for certain specific industrial purposes it may be necessary to stipulate a comparatively low figure.

Occasionally, other tests may be used to recognize contamination. For example, contamination of a clear, light-coloured gas oil with a dark fuel may to some extent be guarded against by stipulating a maximum colour shade or a maximum percentage of asphaltenes (asphaltic material precipitated by certain solvents and indicating presence of residual fuel). On the other hand, a light colour must not be confused with high quality, e.g., colour alone in a diesel fuel is no indication whatever of engine performance.

(*b*) *To ensure that a fuel can be stored, handled, and used satisfactorily* under certain conditions, limits must be placed primarily on flash-point, viscosity, and pour-point.

A flash-point limit is imposed to ensure that the product is not dangerously inflammable under normal storage conditions, and in most countries it is illegal for oil fuels to have flash-points below a certain minimum temperature (usually 150° F closed cup).

For ease of handling, oil fuels must have a certain degree of fluidity, and this characteristic is assessed firstly by a viscosity determination, since beyond a certain viscosity an oil cannot be freely pumped from place to place.

In conjunction with viscosity, the pour-point—popularly supposed to predict the limit of fluidity of the fuel—has a limited value. The test is not always reliable and is of little use by itself, but if the fuel apparently solidifies during the test then one must be cautious in attempting to store or handle the product at or near that solidification temperature. The significance of viscosity and pour-point in ensuring satisfactory use of the fuel is closely allied with their importance in deciding the suitability of the product for specific purposes. This is discussed later.

In certain comparatively rare circumstances a fuel may exhibit instability, manifested by the gradual deposition of small quantities of a carbonaceous or asphaltic sludge on heating or in storage. Alternatively, two fuels may be "incompatible" with each other and tend to deposit sediment on mixing. In all such cases the fuels are initially sediment-free and the quantities of sludge subsequently precipitated are generally quite small, but test methods have been developed to assess these forms of instability. This characteristic is somewhat difficult to define but, fortunately, tests for it are required only on rare occasions.

(*c*) *To ensure the suitability of a fuel for a particular application* many tests may be involved. Some have already been mentioned in connexion with storage and handling, but others are introduced solely because of their significance in relation to the ultimate use of the fuel. Since the test requirements for compression ignition engine fuels differ widely from those for fuel oils (which may be employed in steam-raising, space heating, metal melting, crop drying, etc.), it is better to consider diesel fuels and fuel oils separately in this connexion.

Testing Diesel Fuels

Viscosity may again be instanced as a most important characteristic. With certain types of diesel engine a fuel of unduly low viscosity may cause pump and injector trouble or adversely affect the atomization of the fuel and the lubrication of fuel pump plungers. Generally, however, it is the maximum viscosity which needs control to ensure proper functioning of the pumps and injectors of high-speed units and correct atomization and penetration into the cylinder. To a certain extent too high a viscosity can be remedied by preheating the fuel, but there are limits to which this can be applied.

A second important diesel fuel characteristic is the carbon residue or "coking" test, usually carried out by the Conradson method. It is essential to understand that this test merely compares the relative tendency of fuels to form carbonaceous deposits under bad combustion conditions and does not predict the quantitative amount of coke which will form on atomizer tips and injector nozzles. Both the Conradson and Ramsbottom carbon residue tests are empirical determinations, performed by burning the fuel in a limited air supply under carefully standardized conditions and subsequently weighing the coke residue produced. In a high-speed diesel engine (e.g., an automotive type) a low carbon residue is desirable and frequently under 0·1 per cent is specified. With slower speed units much higher figures are permitted and, while commercial diesel fuels do not normally exceed about 2 per cent Conradson carbon, there are many recorded experiences of large units using under-boiler fuels of about 10 per cent Conradson. These carbon residue tests are of little significance for fuel oils apart from certain types of domestic and small central heating units which require distillate fuels, and, therefore, a Conradson carbon of approximately the same order as for the automotive diesel engine.

Owing to the considerably shorter combustion time available in the high-speed diesel engine operating at rates of the order of 1500 r.p.m., a much closer control of fuel quality is necessary than for the slower speed marine and industrial units. This difference is emphasized by the ignition quality (I.Q.) requirements of the different engine categories. The object of an I.Q. test is to determine the relative ease with which a fuel will ignite in an engine cylinder and this factor is most satisfactorily ascertained in the engine itself. By reference to two standard fuels of cetane number 0 and 100 respectively, the position of any fuel on the cetane scale (i.e., the cetane number) can be determined. For high-speed engines of the automotive type a minimum cetane number of 45 is generally required. As the speed and fuel sensitivity of the engine decrease, however, lower cetane numbers can be tolerated and evidence exists to show that some engines are almost independent of the cetane number of the fuel.

If an engine determination of I.Q. is not possible, a good indication of this characteristic may be obtained on petroleum fuels by determining the temperature of complete miscibility of the fuel with an equal volume of aniline. This test (aniline point) indicates the relative preponderance of paraffinic over aromatic hydrocarbons in the fuel, those fuels of highly paraffinous nature having the highest aniline points and the best ignition quality.

An even better indication is obtained from the diesel index, calculated from the formula

$$\text{Aniline point } (^\circ\text{F}) \times \text{A.P.I. gravity}/100.$$

This test is not infallible and is unsuitable for shale oils, doped fuels, or those of non-petroleum origin.

It is important to note that, whereas a gasoline improves in quality with increase in octane number, this is not necessarily true of diesel fuels and cetane

number. Dependent upon the type of engine and other factors, a maximum desirable ignition quality usually exists: above this, loss of power and higher consumption may result.

The use of a multiplicity of tests achieving much the same object has already been deprecated. Hence, it will be appreciated that there is no point whatever in specifying cetane number, aniline point, and diesel index, since any one of these tests—particularly the cetane number—adequately indicates the ignition quality.

Diesel fuel users frequently specify maximum sulphur contents, partly on account of acidic combustion products (which in certain circumstances may cause corrosive wear) and partly because certain sulphur compounds may attack metal parts. Actually, the second contingency seldom arises, but the increased wear sometimes caused by high sulphur contents cannot be denied. Since sulphur is an inherent property of the crude, however, specification of unnecessarily low sulphur contents is highly undesirable, for this results in restricted production or increased manufacturing cost. It is therefore usual to permit higher sulphur contents in fuels for lower speed units than in those for automotive types.

Volatility plays a certain part in ensuring good combustion in high-speed compression ignition engines, and consequently a distillation test is sometimes introduced when specifying fuels for this purpose. The test is, however, of comparatively little use for fuels for medium and slow-speed units.

It will be noticed that so far only passing reference has been made to the asphaltene test. This test is essentially one for indicating the presence of residual fuels and does not appear to have any particular value in itself, for any indication which it may give of carbon-forming material is generally considered to be more adequately shown by the carbon residue test.

Testing Fuel Oils

Viscosity is certainly the most important individual test in the case of fuel oils. While certain burners cannot atomize the more viscous fuels, the upper viscosity limit frequently depends upon the available storage and handling facilities, for however high the viscosity of the fuel may be at normal storage and handling temperatures, it drops rapidly on heating. For example, a fuel of viscosity, say, 17,000 sec Redwood I at 80° F may be reduced to 6000 sec Redwood I at 100° F, while at the burner tip (where its temperature is, say, 250° F) its viscosity may have dropped to about 100 sec Redwood I, and it can therefore be easily atomized with suitable equipment.

Pour-point, frequently specified for fuel oils, indicates the lowest temperature at which the fuel will just pour or flow when chilled, without disturbance, under certain specified conditions. It is a highly empirical test, dependent to a large extent on the very complicated phenomenon of wax crystallization which, in turn, depends upon the previous thermal history of the fuel and many other conditions. The tendency to regard the pour-point as indicating the limiting temperature at which an oil can be stored satisfactorily is misleading unless closely correlated with low-temperature viscosity.

For example, the fuel referred to two paragraphs back (viscosity 17,000 sec Redwood I at 80° F) would probably have a viscosity of the order of 30,000 sec at 70° F, which is beyond what is usually regarded as the "limit of pumpability". Since, therefore, this fuel becomes virtually unpumpable somewhere between 70° F and 80° F, it is obviously pointless for the user to specify a maximum pour-point of 30° F or even 60° F, which many might be prone to do unless they had carefully considered the matter in all its aspects.

Many of the tests needed for diesel

fuels are unnecessary for fuel oils, but some are important for specific applications: sulphur and ash are among these. Whereas many fuel oil users can afford to ignore these two characteristics, others who are engaged in special process work may find it extremely important for the sulphur or ash to be limited.

Fuel oil is burned to produce heat, but paradoxically the calorific value of petroleum fuels is of comparatively little importance. This is because the difference in calorific value between the heaviest under-boiler fuels and the lightest domestic fuel oils is only something under 8 per cent. Except for carefully conducted fuel consumption tests, it is usually sufficiently accurate to calculate calorific values from published formulae. One of the most frequently used is

$$\text{Cal. val.} = 22{,}320 - 3780d^2,$$

where d = specific gravity. This gives the gross calorific value in British Thermal Units per pound, although in practice it is usually more accurate to reduce the calculated figure by about 1 per cent.

The net calorific value (which is the gross value less the latent heat of vaporization of water produced during combustion) will vary slightly with the hydrogen content of the fuel. Generally speaking, it is about 1080 B.Th.U/lb lower than the gross value.

It will be appreciated that the tests discussed above have been chosen because of their general application. Occasionally it is desirable to introduce additional tests, generally into the manufacturing rather than the marketing specification. Thus, for example, to prevent wide variations in specific gravity which might cause comment, a refiner may decide to set himself certain limits in this connexion, though, at the same time, fully appreciating that they do not necessarily have any technical significance in quality control.

A Typical Diesel Fuel Specification

Let us now imagine that we are a purchasing organization desirous of ensuring forward supplies of a diesel fuel of satisfactory and constant quality. To avoid the pitfalls appertaining to home-made specifications, we might easily turn to a specification compiled by an official body such as the British Standards Institution. This institution issues two diesel fuel specifications: class "A" stipulating the requirements for high-speed diesel engines which require a high standard of performance and class "B" stipulating the requirements of the average marine and industrial unit. The following is a brief summary of the class "B" specification:

Flash-point, P.M. cc	min 150° F
Viscosity, kinematic at 100° F	max 24 centistokes
Carbon residue, Conradson	max 2·0%
Water	max 0·25%
Ash	max 0·03%
Sediment	max 0·1%
Sulphur	max 2·0%
Inorganic acidity	nil
Cetane number	min 23
Calorific value, gross, B.Th.U/lb	min 18,500

It should be noted that:

(*i*) *the fuel may not contain cracked residuum;*

(*ii*) *the viscosity of 24 centistokes is equivalent to 100 sec Redwood. If the viscosity is below 15·5 cs at 100° F (70 sec Redwood I at 100° F) a carbon residue of maximum 2·2 per cent is acceptable.*

(*iii*) *where an engine for the determination of cetane rating is not available, a diesel index of minimum 23 may be substituted.*

We may note, firstly, that this specification includes all the tests for contamination (ash, water, and sediment); the conditions required for storing and handling the fuel are satisfied by the

flash-point and viscosity limits; while restrictions on sulphur, carbon residue, and cetane number ensure its suitability for its application in diesel engines. The minimum cetane number of 23 is very little restriction, since normal commercial diesel fuels lie naturally above this limit. Much the same remark applies to the minimum calorific value specified, since most diesel fuels are automatically of the order of 19,000 B.Th.U/lb.

Two further noteworthy points are that it is not considered desirable to specify limits for pour-point, but that a limit has been placed on inorganic acidity. It is, of course, quite reasonable to demand that a diesel fuel shall not contain free inorganic acid, and all suppliers enforce this automatically.

A Typical Fuel Oil Specification

Although not in quite such common use as the corresponding diesel fuel specifications, the B.S.I. fuel oil specifications are excellent examples because of the logical way in which they have been evolved. Apart from specifications catering for domestic oil-burning installations, the various B.S.I. fuel grades restrict themselves to five tests—namely, flash-point, viscosity, calorific value, water, and sediment.

For example, the following specification for fuels for installations with preheaters and heated storage tanks covers the type of fuel oil which might be used in heavy industry or as a marine fuel for under-boiler use:

Flash-point, P.M. cc	min 150° F
Viscosity, Redwood I at 100° F	max 7000 sec
Calorific value, gross, B.Th.U/lb	min 18,000
Water	max 1·5%
Sediment	max 1·0%

Much higher figures, of course, are allowed for viscosity, water, and sediment than in the diesel fuel specification, and there is an expectation of a lower calorific value.

Footnotes to the specification consider it undesirable to specify limits for:

(*i*) *pour-point, the purchaser being expected to satisfy himself that his equipment is capable of dealing with the fuel at the lowest temperature to which it will be exposed.*

(*ii*) *sulphur content, but it is appreciated that special conditions may demand a limit and provision is made for one to be agreed between purchaser and supplier.*

(*iii*) *ash content, since in general it is so small as to be of little practical importance. However, provision is again made for fuels for special processes* (vide "*sulphur*").

The B.S.I. specification is not entirely above criticism. For example, the sediment content is probably unnecessarily high, since commercial supplies rarely contain more than 0·25 per cent sediment, and the limit on calorific value is probably unnecessary, since this property is largely controlled by the origin and other characteristics of the fuel. Nevertheless, it is confidently recommended as a good example of a workable specification without frills or fanciful ideas.

In conclusion, let it be said that oil fuel specifications are a very necessary guide to refiners, marketers, and users—always providing that they are employed with intelligence and with due regard to the circumstances for which they are needed.

Vacuum Oil Company Ltd. announce that *Lt.-Col. S. J. M. Auld*, O.B.E., M.C., D.Sc., F.Inst.Pet., having reached the company's normal retirement age, has relinquished his position as chief technologist and will henceforward act as a petroleum consultant to the company. Col. Auld's place will be taken by Dr H. M. Davies, Ph.D., A.R.I.C., F.Inst.Pet., who has been appointed manager of laboratories with responsibility for all technological matters.

A French merchant vessel taking on bunker fuel oil at the North end berth.

NEW MARINE BUNKER FACILITIES AT ALGIERS

A new marine bunker installation on the Jetée de l'Est, Algiers, which can deliver bunker fuel to ships alongside at a rate exceeding 1200 tons an hour, was formally opened by the Governor-General of Algeria, Mr Naegelen, on April 23.

The installation is operated by the well-known French firm Cie Venture-Weir, agents in France and Algiers of the British Mexican Petroleum Co. Ltd.

Designed by Mr J. E. Jenkin, chief engineer, Anglo-American Oil Company, and carried out locally under the supervision of his assistant engineer, Mr A. V. Edwards, the building of the depot was started in May 1946 and was ready for operation in July 1948.

Building of the new installation presented a variety of constructional problems. These had to take into account the restricted space of the site, its isolation in the harbour, cut off from direct communication with the mainland, and the fact that the placing of petroleum equipment in the midst of the natural beauty of Algiers was liable to impair the aesthetic conception of the port. To satisfy these demands the depot was built in such a way as to consist of seven squat tanks of 4000 tons each, whose height barely exceeded that of the sea wall of the jetty.

A boiler-house complete with steam and electric pumping facilities was designed to enable tankers to discharge up to 1400 tons an hour. The largest tankers afloat can be accommodated alongside.

This modern installation replaces a floating station for the supply of bunker fuels which was first mooted in 1914 by the firm of Michel Venture et Fils. But it was not until 1920 that the first vessel of 800 tons was introduced. This was subsequently replaced by a hulk of 5000

North end of the installation. The height of the oil tanks barely exceeds that of the sea wall; thus the view is not spoiled.

tons. Between 1920 and 1936 the floating depot grew in varying stages, finally consisting of the hulks of two tankers, *Francunion V* and *VI*, and two dumb barges, with a total capacity of 18,600 tons.

Due to the greatly increased demand for bunkers at Algiers and the growing size of tankers, it became evident that a land installation was required. While the first official approach to the authorities was made in May 1937, proposing the substitution of the floating depot by a land installation, the intervening period of the war temporarily stopped proceedings. These were only resumed in October 1943 and closed successfully in November 1945.

Meanwhile, after the liberation of Algiers, the bulk of the Allied seaborne operations which were directed on Italy were much assisted by the services of this floating equipment, which, although partially damaged by the Germans through air bombing, was still largely in a condition to operate in the bunkering of Allied navies and convoys and was placed entirely at the disposal of the Allied forces.

Full credit for the successful outcome of the negotiations belongs to Cie Venture-Weir, through whose perseverance and co-operation with the Algerian authorities the construction was able to proceed.

LONDON BRANCH

At their meeting on April 26, members of the London Branch had an interesting address on "Oilfield development". The lecturer was J. B. Kay and he answered many questions on points of detail.

On May 24, J. L. Taylor presented a paper on "Coal and Oil", in which he dealt comprehensively with these fuels, and their utilization in their respective spheres.

M.I.R.A. PROVING GROUND

The proving ground of the Motor Industry Research Association at Lindley, near Nuneaton, Warwickshire, was officially opened by the President of the Association, L. P. Lord, on April 28. After the opening ceremony there was a drive past by nearly 100 vehicles representative of current types of motorcycles, cars, and commercial vehicles produced by the industry. A selection of vehicles then demonstrated various test methods and equipment.

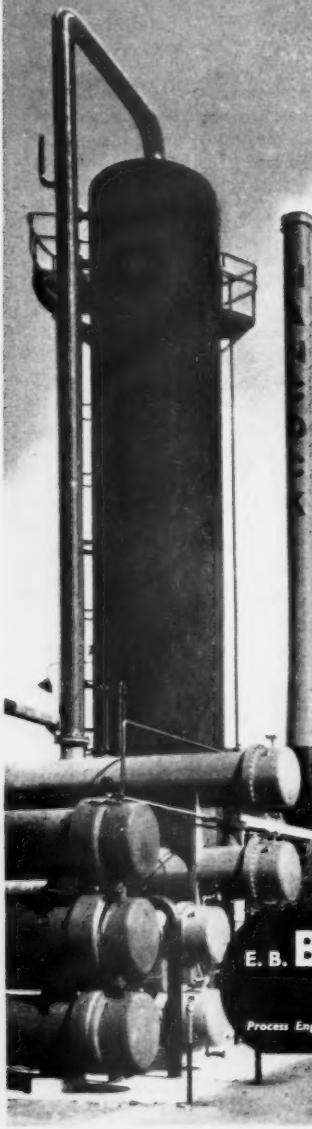
A small exhibit was arranged to illustrate some of the Association's work, and contained a few instruments representative of the type of equipment which will gradually be made available at the proving ground for the use of members of the Association.

The site has a perimeter track, which is about 3¼ miles long and 50 ft wide, and there are three intersecting runways each 150 ft wide, the longest of which is about 2000 yards.

The proving ground is not yet equipped for some types of tests which are necessary fully to "prove" a vehicle, but it is possible with the existing facilities for numerous tests to be carried out with greater control and safety and in considerably less time than on the public highway.

Already the perimeter track and runways have been converted into a series of road circuits and straights, with timing devices on the latter, and a small meteorological station has been installed. Accelerometers and other simple instruments will shortly be available, and to compensate for the absence of hills on the site, a dynamometer trailer car has been designed and is being built at the M.I.R.A. laboratory for imposing easily adjustable loads and automatically controllable speeds on towing vehicles. This item of equipment, which, if successful, will be supplemented by another of greater capacity, should be available for general use in the summer.

eliminating smog at a profit



Pictured here is what we believe to be the first plant attacking the problem of atmospheric contamination by sulphur-bearing gases logically, effectively and profitably.

Hancock Chemical Company of California receives hydrogen sulphide removed from the fuel gases of nearby oil refineries and converts it to elemental sulphur which is sold for the manufacture of sulphuric acid.

The refiners benefit by the elimination of noxious fumes from stack gases, thereby improving maintenance and operation efficiency, and by the reduction of corrosion.

The return from the sale of the sulphur provides an attractive return on the plant investment.

The community benefits by the removal of many *tons a day* of sulphur from the atmosphere.

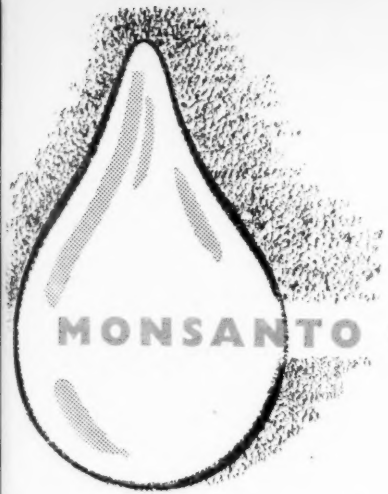
Initial operations of this plant have been so successful that plans are now being made for doubling the capacity of the installation.

Operating and investment cost data for plants of this type may be readily obtained from any Badger office.

E. B. **BADGER** & SONS (GREAT BRITAIN) LTD.

99 ALDWYCH LONDON W.C.2.

Process Engineers and Constructors for the Petroleum, Chemical and Petro-Chemical Industries



MONSANTO OIL ADDITIVES

for better lubricants

SANTOLUBE 394-C ANTIOXIDANT

For oil stability at high crankcase temperatures

SANTOLUBE 203-A DETERGENT

Ensures engine cleanliness and freedom from piston ring sticking

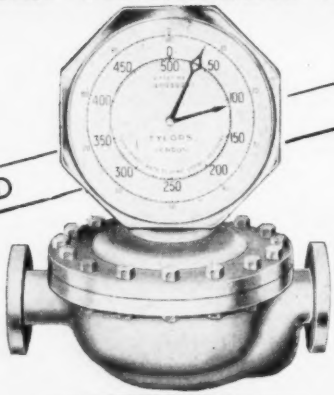
SANTOPOUR-B POUR POINT DEPRESSANT

Maintains oil fluidity at low temperature

For further information on **OIL ADDITIVES** write Petroleum Chemicals Department

MONSANTO CHEMICALS LIMITED
VICTORIA STATION HOUSE, LONDON, S.W.1

VOLUMETERS FOR OIL, PETROL AND OTHER PETROLEUM PRODUCTS



ACCURACY MAINTAINED

BALANCED PERFORMANCE RUGGED CONSTRUCTION

APPROVED BY THE BOARD OF TRADE (Standards Department)

TYLORS LIMITED

BELLE ISLE

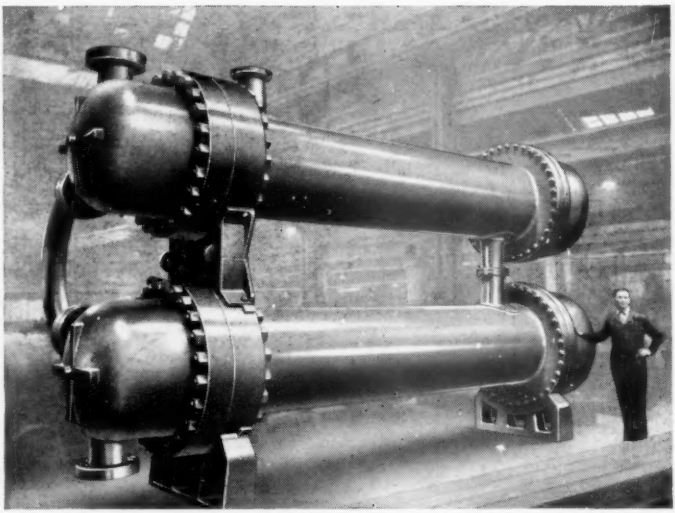
ESTABLISHED 1777 **LONDON, N.7** 'PHONE: NORTH 1625

MADE from special material that not only resists "creep" at elevated temperatures, but also resists embrittlement from exposures to high temperature stresses and retains high tensile strength at elevated temperatures.

W. MARTIN WINN LTD. DARLASTON S. STAFFS.

PHONE: DARLASTON 72, 73 & 74 GRAMS: "ACCURACY" DARLASTON

HEAT EXCHANGE EQUIPMENT



HIGH PRESSURE HEAT EXCHANGERS

Surface per Unit	... ...	2170 sq. feet
Working Pressure in Tubes	...	1500 lb. per sq. inch

These two Units form part of a battery comprising 60 similar Units and having a Crude Oil throughput of 4½ million gallons per day.

A. F. CRAIG & CO., LTD.

CALEDONIA ENGINEERING WORKS

PAISLEY——————SCOTLAND

London Office: SALISBURY HOUSE, LONDON WALL, E.C.2

Telephone: MONarch 4756

American Associates:

THE KOCH ENGINEERING COMPANY, INC., WICHITA, KANSAS

Printed by Jarrold & Sons, Ltd., Norwich

THE Metal Containers PAIL
-closes easily
PRIOR TO CLOSING
SEALED
DIE-CURLED LIP
JOINTLESS RUBBER SEAL
STRENGTHENING BEAD
-opens easily
OPENING
SCREWDRIVER
-pours easily
POURER SPOUT
OVERSEAL
FINGER RING
CLOSED
OPEN
With its hermetic, liquid-tight closure and reduced bottom for ease of stacking the Metal Containers Pail can in addition be equipped with standard fittings such as a press-cap to be used when packing liquids. Capacity range at present is 2, 3, 4 and 5 gallons.

METAL CONTAINERS LTD., 17 WATERLOO PLACE, PALL MALL, LONDON
WORKS: ELLESMERE PORT & RENFREW. ASSOCIATED COMPANIES OVERSEAS